Parametric Study of Pin Surface Used to Suppress Undesired Modes in a Packaged W-band Microstrip Receiver

Ainara Rebollo, Itziar Maestrojuán, Belén Larumbe-Gonzalo, Ramón Gonzalo and Iñigo Ederra
Antenna Group
Electrical and Electronic Engineering Department
Public University of Navarra
Pamplona, Spain
Email: ainara.rebollo@unavarra.es

***Abstract*—A pin surface structure has been used in order to suppress undesired modes in a packaged W-band RF front-end receiver. A parametric analysis has been carried out in order to determine the optimum dimensions. Resonances suppression has been demonstrated.**

***Index Terms*—Microstrip packaging; W-band; pin surface; lid of nails**

I. Introduction

A broadband and differential RF front-end receiver operating in W-band has been designed in planar technology over Rogers RT/duroid 5880 substrate, with dielectric constant 2.22 and thickness 127μm [1]. However, when packaging this circuit, the excitation of cavity modes and, also, surface modes in the dielectric substrate may penalize the transmission of the quasi-TEM mode in the microstrip circuit.

Several studies have been published tackling this matter using periodic structures. These forbid propagation of EM waves inside its stop-band and, as a consequence, cavity modes are avoided. Periodic structures such as Bed of Springs [2], Fakir's Bed of Nails [3] and Mushroom-Type Electromagnetic Band Gap (EBG) [4] are more suitable for low frequency because of its manufacture and besides, the use of dielectric in the second case increases the losses of the structure.

Nevertheless, other periodic structures operating at higher frequencies have also been presented. On the one hand, the use of EBG holes inserted in the upper metal plate of a shielded microstrip structure [5] allows the suppression of undesired cavity modes in a narrow stop-bandwidth centred at 76GHz. On the other hand, the new gap-waveguide presented in [6] implements a periodic structure consisted of a lid of nails or a pin surface whose main advantage is its large stop-bandwidth. The demonstration around 15GHz of the cavity mode suppression of this textured structure, which does not use a dielectric substrate, has been first presented in [7]. Moreover, one application of this periodic structure can be found in [8] where the lid of nails is implemented for packaging the ports of eleven antenna in a frequency range from 5GHz to 13.5GHz.

Therefore, in this study, the selected structure is this metal pin surface or lid of nails due to its large stop-bandwidth, easy manufacturing, low losses and its potential use at high frequency such as W-band.

The geometry of a pin surface is shown in Fig. 1. The pin surface implemented in the upper metal of the package covers the microstrip circuit keeping an air gap between the end of the pin and the substrate. The height of the gap and also, the length, the period and the size of the pins are the parameters that optimize the stop-bandwidth.

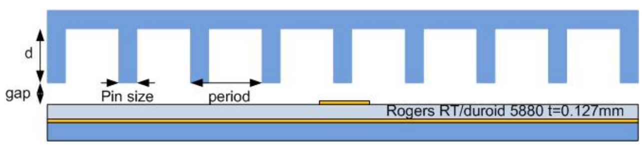

Fig. 1. Pin surface structure.

The present paper describes a parametric study of a pin surface in order to suppress unwanted modes in a packaged W-band microstrip circuit on 127μm thick Rogers RT/duroid 5880 substrate. Finally, the performance of the packaged W-band microstrip circuit with the proposed periodic structure is validated.

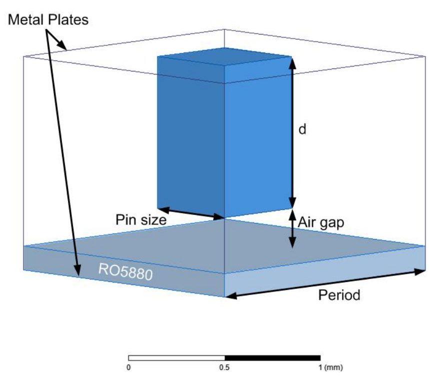

Fig. 2. Unit cell and its parameters.

II. Parametric Study of Pin Surface

For the analysis of the periodic structure we considered the unit cell that can be shown in Fig. 2 where the main parameters to be taken into account are defined. For this aim, the definitions of periodic boundary conditions in both sides and of PEC surface in bottom and top are necessaries. Ansoft HFSS has been used in order to obtain the dispersion diagrams of the first four propagation modes.

The first step to study the cut-off properties of a lid of nails is to fix the pin length d equal to $\lambda_c/4$ [7], i.e. 0.81mm at 92.5GHz. Afterwards, the effects of the distance between pins, period, the pin size and the height of the air gap have been analysed.

The stop-bandwidth in this periodic structure is determined by the two lowest order modes: the upper dispersion frequency of the first order mode defines the lower limit of the stop-band and the lower dispersion frequency of the second order mode defines the upper limit. These limits have been studied for each parameter value.

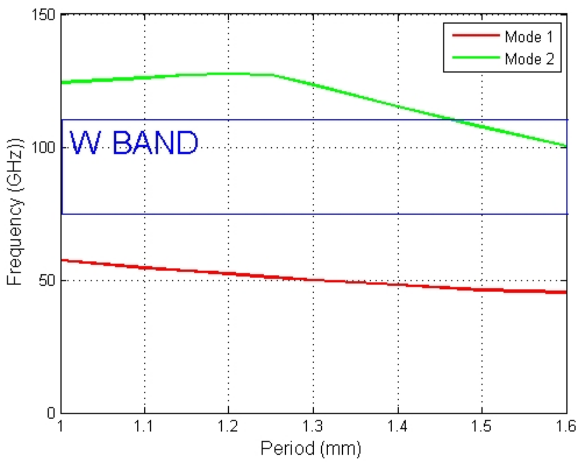

Fig. 3. Upper (second propagation mode) and lower (first propagation mode) limits of the bandwidth depending on the distance between pins.

The dependence on the period is presented in Fig. 3. The structure avoids the propagation of undesired waves in the frequency range between the solid lines plotted in this figure. For small periods, the gap increases along with the period. However, when the period is increased above 1.2mm, the upper limit of the stop-bandwidth decreases because the space between the pins are wide enough to allow the propagation of some undesired modes in the air. Therefore, the optimum period in terms of largest bandwidth, i.e. 1.2mm, was selected.

Fixing the period of the structure at 1.2mm, the study of the pin size has been considered, as shown in Fig. 4. The limits of the stop-bandwidth are almost unaffected by this parameter because the variation of this parameter is not large enough to allow the change of the propagation performance of the modes. However, as we can observed in the limits of the figure, the stop-band decreases for values below 0.3mm and above 0.5mm.

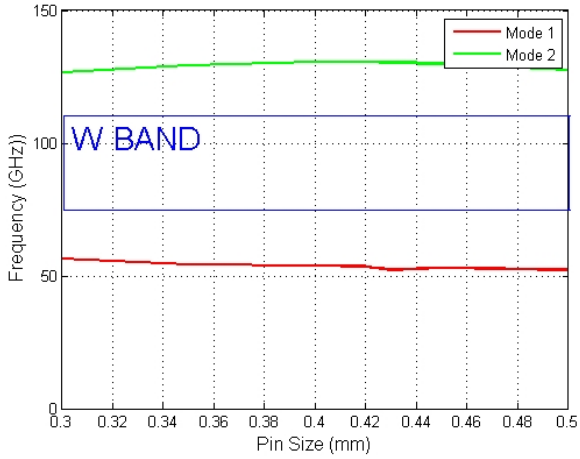

Fig. 4. Upper (second propagation mode) and lower (first propagation mode) limits of the bandwidth depending on the pin size. The period of the structure is 1.2mm.

Finally, the effect of the air gap is shown in Fig. 5. The larger the gap, the narrower the stop-bandwidth because capacity effects appear between the lower metal plate and the flat surface of the pins. Therefore, a 0.173mm air gap has been selected in order to obtain a stop-bandwidth of the periodic structure covering the full W-Band.

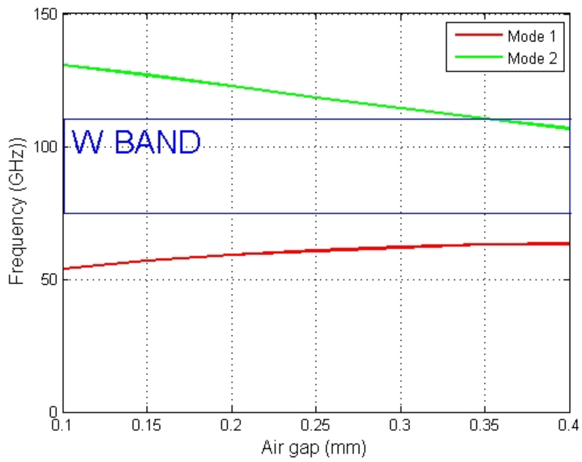

Fig. 5. Upper (second propagation mode) and lower (first propagation mode) limits of the bandwidth depending on air gap height. The period and the size of the pin are 1.2mm and 0.4mm respectively.

The dispersion diagram of the first four propagation modes in the optimum pin surface structure (d= 0.81mm, period= 1.2mm, pin size= 0.4mm and air gap= 0.173mm) and its stop-bandwidth can be seen in Fig. 6, where β is the propagation constant of the modes of the periodic structure and d is the period of the unit cell. As we expected according to the parametric study, the stop-bandwidth determined by the first two propagation modes covers the full W-band.

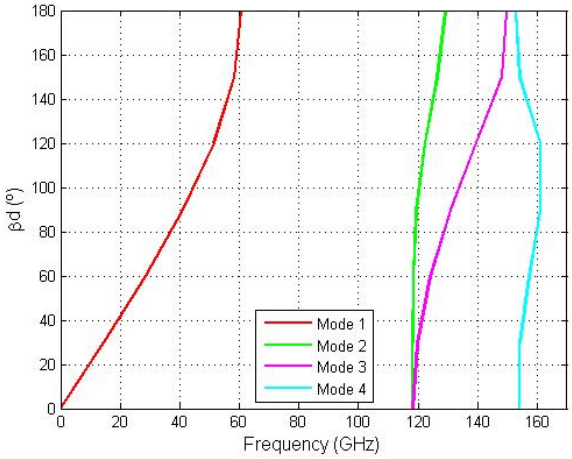

Fig. 6. Dispersion diagram of the pin surface covering a microstrip circuit over 127μm thick Rogers RT/duroid 5880 substrate. The length and the size of the pin, and the heigth of the air gap are 1.2mm, 0.4mm and 0.173mm respectively.

III. Structure Performance

Two analysis have been realized in order to validate the use of the proposed pin surface structure in the packaged W-band microstrip circuit.

On the one hand, the S parameters of a W-band microstrip circuit inside a smooth metal cavity whose heigth is 1.127mm have been obtained as can be shown in Fig. 7. In this figure, many resonances can be seen, created by the cavity mode propagation.

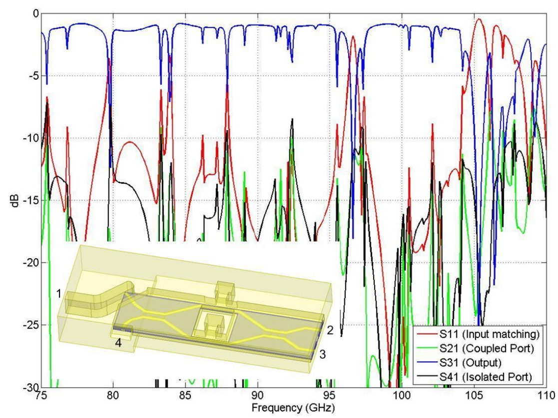

Fig. 7. The S parameters of a W-band microstrip circuit inside a smooth metal cavity. The schematic of this simulated structure is also included.

On the other hand, the S parameters have been calculated when the pin surface is introduced on the top layer of the same cavity, see Fig 8. The resonances produced by the packaging are removed when the pin surface is used.

In order to illustrate the effect of the pin surface in the removal of cavity modes at one selected frequency, i.e. 92.5GHz, the 2-D color plots of the distributions of the electric field

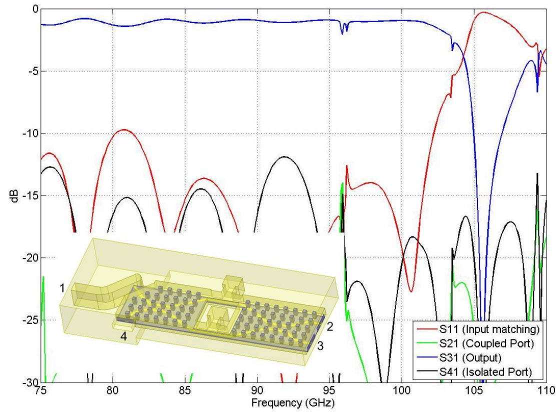

Fig. 8. The S parameters of a W-band microstrip circuit inside a metal cavity in whose top layer a pin surface is introduced. The schematic of this simulated structure is also included.

magnitude inside the cavity have been obtained for the two packaged cases that we considered before. These can be seen in Fig. 9 and 10. When a lid of nails is implemented on the top layer of the cavity, the undesired modes that penalize the propagation of the quasi-TEM mode in the microstrip circuit are removed.

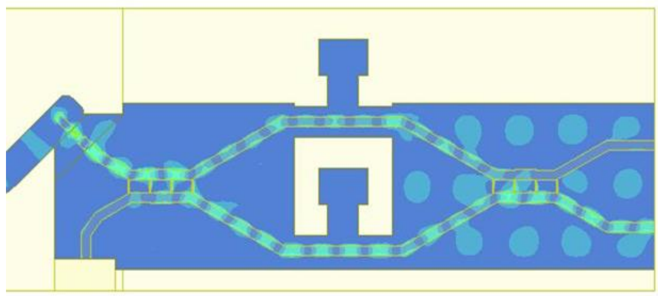

Fig. 9. 2-D color plot of the magnitude of the electric field at 92.5GHz of a W-band microstrip circuit inside a smooth metal cavity.

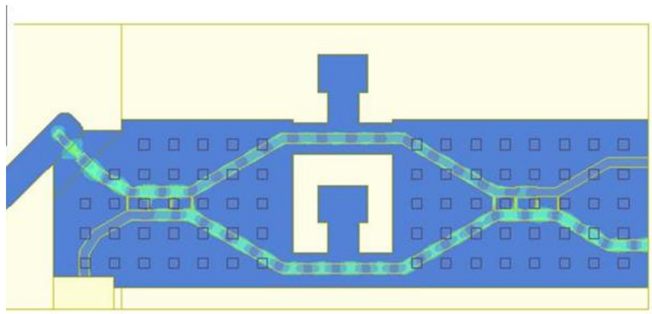

Fig. 10. 2-D color plot of the magnitude of the electric field at 92.5GHz of a W-band microstrip circuit inside a metal cavity when a pin surface is introduced on the top layer.

IV. CONCLUSION

In this paper, a parametric study of a pin surface has been realized in order to suppress the propagation of undesired modes in a packaged W-band microstrip circuit. Moreover, the performance of the optimized pin surface has been demonstrated by simulation in Ansoft HFSS.

ACKNOWLEDGMENT

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